

**GPSA ENGINEERING DATABOOK ERRATA
(2004 FPS Edition)**

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vapor recovery

Equipment or process for the recovery of desired components from stock tank vapors or vapors from some other source.

volatile sulfur

An obsolete term referring to sulfur compounds that will vaporize readily (See sulfur).

weathering

The evaporation of liquid caused by exposing it to the conditions of atmospheric temperature and pressure. Partial evaporation of liquid by use of heat may also be called weathering.

weathering test

A GPA test for LP-gas for the determination of heavy components in a sample by evaporation under specified conditions.

weight in air

Weight compared to a standard with no correction for air buoyancy.

wellhead

The assembly of fittings, valves, and controls located at the surface and connected to the flow lines, tubing, and casing of the well so as to control the flow from the reservoir.

wet gas

(1) A gas containing water, or a gas which has not been dehydrated. (2) A term synonymous with rich gas. Refer to definition of "rich gas".

Wobbe number

A number proportional to the heat input to a burner at constant pressure. In British practice, it is the gross heating value of a gas divided by the square root of its gravity. Widely used in Europe, together with a measured or calculated flame speed, to determine interchangeability of fuel gases.

Conversion Factors

In these tables, factors for conversion, including conversions to the International System of Units (SI), are based on ASTM Standard for Metric Practice, E380-91. The latest edition of this publication should be studied for more detail on the SI system, including definitions and symbols.

In calculating derived factors in the tables that follow, exact conversions were used, when available, rather than the 7-digit round-offs listed in ASTM E380 conversion tables. Derived factors given below are rounded to the same number of significant digits as the source factors.

In any conversion of fundamental measurement units, some confusion may result due to redefinition of units used in earlier tables. For example, in 1959 a small refinement was made in the definition of the yard, which changed its length from 3600/3937 meter (or 1 inch = 25.4000508 mm) to 0.9144 m exactly (or 1 inch = 25.4 mm exactly). The tables below are based on the new definition, but one should be aware that

where U.S. land measurements are concerned, the old relationship applies. Refer to ASTM E380-91, note 13, for more detail.

Energy Units Conversion

Confusion may arise in the definition of units for heat or energy. In the tables below, the Btu (IT) and calorie (IT) are used. These are the heat units recommended by the International Conference on the Properties of Steam, as defined:

$$1 \text{ Btu (IT)} = 1055.05585262 \text{ joule (exactly)}$$

$$1 \text{ Calorie (IT)} = 4.186800 \text{ joule (exactly)}$$

For information only, other definitions that may be used elsewhere:

$$1 \text{ Btu (Mean)} = 1055.87 \text{ joule}$$

$$1 \text{ Btu (39°F)} = 1059.67 \text{ joule}$$

$$1 \text{ Btu (60°F)} = 1054.68 \text{ joule}$$

$$1 \text{ Btu (Thermochemical)} = 1054.350 \text{ joule}$$

$$1 \text{ calorie (Mean)} = 4.19002 \text{ joule}$$

FIG. 1-2

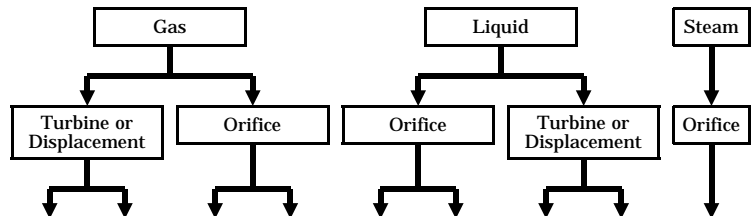
Conversion Factor Tables

| Velocity (Length/unit of time) | | | | | | |
|-----------------------------------|----------|-------------------------|-----------------------|----------|----------|--|
| ft/sec | ft/min | Miles/hr (U.S. Statute) | m/sec | m/min | km/hr | |
| 1 | 60 | 0.6818182 | 0.3048 | 18.288 | 1.09728 | |
| 0.01666667 | 1 | 0.01136364 | 5.08×10^{-3} | 0.3048 | 0.018288 | |
| 1.466667 | 88 | 1 | 0.44704 | 26.8224 | 1.609344 | |
| 3.280840 | 196.8504 | 2.236936 | 1 | 60 | 3.6 | |
| 0.05468066 | 3.280840 | 0.03728227 | 0.016667 | 1 | 0.06 | |
| 0.9113444 | 54.68066 | 0.6213712 | 0.2777778 | 16.66667 | 1 | |

| Energy | | | | | | |
|-----------|-----------|---------------------------|---------------------------|---------------------------|---------------------------|-----------|
| Ft-lbf | Kgf-meter | Btu (IT) | Kilo-calorie (IT) | Hp-hr | Kilowatt-hr | joule (J) |
| 1 | 0.1382550 | 1.285068×10^{-3} | 3.238316×10^{-4} | 5.050505×10^{-7} | 3.766161×10^{-7} | 1.355818 |
| 7.233014 | 1 | 9.294911×10^{-3} | 2.342278×10^{-3} | 3.653037×10^{-6} | 2.724070×10^{-6} | 9.806650 |
| 778.1692 | 107.5858 | 1 | 0.2519958 | 3.930148×10^{-4} | 2.930711×10^{-4} | 1055.056 |
| 3088.025 | 426.9348 | 3.968321 | 1 | 1.559609×10^{-3} | 1.163×10^{-3} | 4186.8 |
| 1980000 | 273744.8 | 2544.434 | 641.1865 | 1 | 0.7456999 | 2684520. |
| 2655224 | 367097.8 | 3412.142 | 859.8452 | 1.341022 | 1 | 3600000. |
| 0.7375621 | 0.1019716 | 9.478171×10^{-4} | 2.388459×10^{-4} | 3.725061×10^{-7} | 2.777778×10^{-7} | 1 |

FIG. 3-2

Flow Calculation Guide



| Factors | Units ⇒ | Gas | | Liquid | | Liquid | | Steam | | Fig. # | |
|---------------------------------------|----------------------------------|---------------|---------------|---------------|---------------|---------------|------------|---------------|------------|--------|---------|
| | | Mass lb/hr | Vol scf/hr | Mass lb/hr | Vol scf/hr | Mass lb/hr | Vol gph | Mass lb/hr | Vol gph | | |
| Square Root of Differential | $\sqrt{h_w}$ | — | — | • | • | • | • | — | — | • | — |
| Square Root of Static Pressure | $\sqrt{P_f}$ | — | — | — | • | — | — | — | — | — | — |
| Orifice Factor (KEY) | $F_n \bullet$ ($F_c + F_s$) | — | — | • | • | • | • | — | — | • | 3-13 |
| Pressure Base Factor | F_{pb} | — | • | — | • | — | — | — | — | — | 3-4 |
| Flowing Temperature Factor | F_{tf} | — | — | — | • | — | — | — | — | — | 3-4 |
| Temperature Factor | F_{tm} | — | • | — | — | — | — | — | — | — | 3-1 |
| Temp Correction Factor (Liquids) | C_{tl} | — | — | — | — | — | — | — | • | — | 3-1 |
| Pressure Correction Factor (Liquids) | C_{pl} | — | — | — | — | — | — | — | • | — | 3-4 |
| Pressure Factor | F_{pm} | — | • | — | — | — | — | — | — | — | 3-1 |
| Supercompressibility Factor | F_{pv} | — | — | — | • | — | — | — | — | — | 23-4 |
| Square of Supercompressibility Factor | S | — | • | — | — | — | — | — | — | — | 3-1 |
| Density | ρ | • | — | — | — | — | — | • | — | — | 3-1 |
| Square Root of Density | $\sqrt{\rho}$ | — | — | • | — | • | — | — | — | • | — |
| Specific Gravity Factor — Gas | F_g | — | — | — | • | — | — | — | — | — | 3-4 |
| Gravity-Temperature Factor — Liquid | F_{gt} | — | — | — | — | — | • | — | — | — | 3-4 |
| Meter Factor | MF | • | • | — | — | — | — | • | • | — | 3-1 |
| Count (Volume) | CNT | • | • | — | — | — | — | • | • | — | 3-1 |
| Constant | | | | 1.0618 | | 1.0618 | | | | | |
| Steam Factor | F_s | | | | | | | | | • | 3-27/28 |
| Expansion Factor | Y | — | — | • | • | — | — | — | — | • | 3-1 |
| Temperature Base Factor | F_{tb} | — | • | — | • | — | — | — | — | — | 3-4 |
| Orifice Thermal Expansion Factor | F_a | — | — | • | • | • | • | — | — | • | 3-4 |

Notes:

1. This guide is intended for use in obtaining approximate flows when used in conjunction with data contained in this section as referenced in the far right hand column.
2. To obtain flow, substitute areas containing dots with known numbers and multiply top to bottom.
3. The number of factors used may vary depending on method of calculation in specific application, content of flowing stream, and individual contractual agreements.
4. Factors appearing in shaded areas are not generally necessary for calculating approximate flows.
5. The factors F_{pv} , S, C_{tl} , C_{pl} , Y, and F_a must be obtained for the specific substance being measured.



- Check the inside of tube section for accumulation of grease, dirt, bugs, leaves, etc., and schedule cleaning before tubes become packed with such debris.

NOISE CONSIDERATIONS

Fan noise can be elusive requiring sophisticated equipment to measure accurately. Fan noise control must begin at the air-cooled heat exchanger design stage. Noise control, as an after thought, can result in a very costly fan and drive component retrofit, and possible addition of heat transfer surface or acoustic barriers. Acoustic barriers may increase the pressure drop the fan must overcome; hence, bigger fans and more horsepower will be required.

FIG. 10-18

Air Static-Pressure Drop

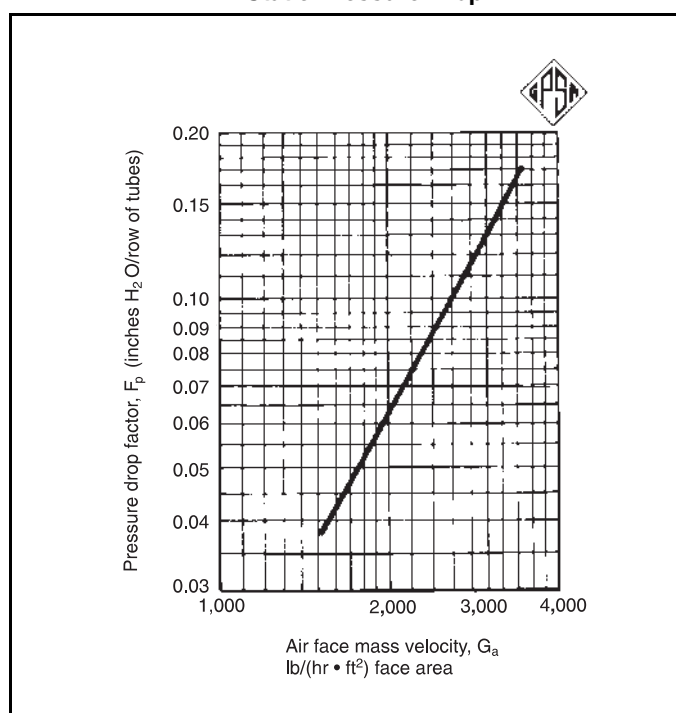


FIG. 10-19

Correction Factor for Fluid Viscosity Within the Tubes

| Correction factor * when $\phi = \left(\frac{\mu}{\mu_w}\right)^{0.14}$ | (See Fig. 10-13) |
|---|---------------------------|
| | Correction Factor, ϕ |
| 1. Hydrocarbon vapor; steam; water | 1.0 |
| 2. Hydrocarbon liquids (18 to 48 API), MEA/DEA solutions | 0.96 |
| 3. Water/glycol solutions; heat transfer fluids | 0.92 |
| 4. Lube oils; heavy petroleum fractions (10 to 18 API) | 0.85 |

* When $N_r < 17$, $\phi = \left(\frac{\mu}{\mu_w}\right)^{0.25}$ A Reynolds number of less than 17 is only likely for lube oils or heavy petroleum fractions. The minimum recommended value of ϕ to use in Step 10 is 0.80, even though the calculated value may be lower.

Since noise (Sound Pressure Level) is a function of tip speed, slowing fan rotation can reduce noise.

Unfortunately, a fan's pressure capability decreases with the square of the speed. Therefore, the fan's pressure capability must increase to maintain the required airflow.

To increase the pressure capability of a fan, the fan's solidity ratio must be increased, by adding more blades, or using blades with a wider chord, such as a low-noise blade design. Unfortunately, increasing the number of blades can reduce fan efficiency.

Noise requirements are often more restrictive at night. If this is a consideration, slowing the fan as ambient temperature drops using a variable-speed drive can be one solution to reducing noise. As the nighttime ambient temperature drops, required airflow is reduced, therefore fan speed may be slowed to lower noise levels.

Noise-Related Nomenclature

Decibel:

A number representing relative sound intensity expressed with respect to a reference pressure or power level. The usual reference for sound pressure level is of 20 micro newtons per square meter ($20 \mu\text{m}^2$). A decibel is a logarithm (base 10) of a square of the power values abbreviated "dB".

Frequency:

Sound vibration rate per second in Hertz (cycles per second).

Low-Noise Fans:

A fan able to operate at low speed due to its high-pressure capability. Fan pressure capability is a function of its solidity ratio. Therefore, a low-noise fan will generally have more or wider blades than would be required if the fan operated at normal tip speeds.

Octave Bands:

Noise is categorized by dividing it into separate frequency bands of octaves or 1/3 octaves. Generally, 63, 125, 250, 500, 1K, 2K, 4K and 8K center frequencies are used to define noise bands in Hertz (cycles/sec).

Sound Power Level:

Acoustical power (energy) can be expressed logarithmically in decibels with respect to a reference power, usually 10^{-12} watts. The relationship is given as: Sound Power Level.

$$\text{PWL} = 10 \log \left(\frac{W}{10^{-12} \text{ watts}} \right) \quad \text{Eq 10-3}$$

Sound power level cannot be measured directly but must be calculated from sound pressure levels (SPL) dB. In metric terms, this is known as L_w .

Sound pressure level, known as SPL, or L_p in metric terminology, is the audible noise given in decibels that relates to intensity at a point some distance from the noise source. It can be related to octave bands or as an overall weighted level dB(A).

Weighted sound levels relate the decibel (loudness) to a frequency. Ears can easily pick up high-frequency noises (both intensity and direction) but are relatively insensitive to low-frequency noise. For a stereo system high-frequency speakers must be very carefully located in a room for best results, but low-frequency bass speakers can be placed anywhere, even out of sight.

There are three basic weighting systems: A, B and C. The "A" system, dB(A), most closely relates to our ear, the "B" sys-

FIG. 10-20
Altitude and Atmospheric Pressures⁸

| Altitude above Sea Level | | Barometer | | Atmospheric Pressure | |
|--------------------------|--------|------------|------------|----------------------|--------|
| meters | feet | mm Hg abs. | in Hg abs. | kPa (abs) | psia |
| 0 | 0 | 760.0 | 29.92 | 101.325 | 14.696 |
| 153 | 500 | 746.3 | 29.38 | 99.49 | 14.43 |
| 305 | 1000 | 733.0 | 28.86 | 97.63 | 14.16 |
| 458 | 1500 | 719.6 | 28.33 | 95.91 | 13.91 |
| 610 | 2000 | 706.6 | 27.82 | 94.18 | 13.66 |
| 763 | 2500 | 693.9 | 27.32 | 92.46 | 13.41 |
| 915 | 3000 | 681.2 | 26.82 | 90.80 | 13.17 |
| 1068 | 3500 | 668.8 | 26.33 | 89.15 | 12.93 |
| 1220 | 4000 | 656.3 | 25.84 | 87.49 | 12.69 |
| 1373 | 4500 | 644.4 | 25.37 | 85.91 | 12.46 |
| 1526 | 5000 | 632.5 | 24.90 | 84.32 | 12.23 |
| 1831 | 6000 | 609.3 | 23.99 | 81.22 | 11.78 |
| 2136 | 7000 | 586.7 | 23.10 | 78.19 | 11.34 |
| 2441 | 8000 | 564.6 | 22.23 | 75.22 | 10.91 |
| 2746 | 9000 | 543.3 | 21.39 | 72.39 | 10.50 |
| 3050 | 10 000 | 522.7 | 20.58 | 69.64 | 10.10 |

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tem, dB(B), has some specific uses and the "C" system, dB(C), is considered unweighted.

The dB(A) is the most common weighting system. It expresses sound levels with a single number instead of having to specify the noise of each octave band.

Note that the sound range of ACHEs (at close range) is typically between 80 and 105 dB(A).

ACHE Noise

Whether the concern is for overall plant noise or the noise exposure of plant workers in the vicinity of the fans, a different type of noise specification must be used.

Overall, noise limitations from an ACHE are typically a sound power level (PWL) specification for each unit. This limits the contribution of each unit (typically two fans) to the plant noise as a whole. This is usually needed where noise at the plant boundary is considered. Contributions of each part of the plant must be carefully controlled if overall plant noise is limited. PWLs can be expressed as weighted level dB(A) or sometimes even by limitations on each octave band.

If worker protection is the main concern, a limitation of sound pressure level at 3 ft or 1 m below the bundle will probably be imposed as "SPL dB(A) at 3 ft". The OSHA limitation is 90 dB(A) for eight-hour exposure, but 85 dB(A) down to 80 dB(A) is not uncommon.

Predicting Fan Noise

Each fan manufacturer has proprietary equations for predicting fan noise. API Guidelines use the general formula:

$$PWL = 56 + 30 \log \left(\frac{FPM}{1000} \right) + 10 \log HP \quad \text{Eq 10-4}$$

This calculates PWL as dB(A)

Proprietary noise equations are based on actual tests at various speeds and operating conditions considering the following effects:

- Fan diameter
- Fan tip speed
- Blade Type
- Blade pitch angle
- Inlet conditions
- Horsepower

Note: Logs are common logs (base 10).

For example:

14 ft fan

237 RPM (10,424 FPM tip speed)

25.1 HP

Find sound power level

$$PWL = 56 + 30 \log 10.4 + 10 \log 25.1 \\ = 100.5 \text{ dB(A)}$$

- When considering multiple noise sources (fans) use the relation:

$$PWL_N = PWL + 10 \log N \quad \text{Eq 10-5}$$

The sound power level for 2 adjacent fans is the PWL of one fan plus 10 log 2 or $PWL_2 = PWL + 3$.

A doubling of the noise source adds 3 dB.

- Noise attenuates with distance by the equation:

$$SPL \text{ (at distance R)} = PWL - 20 \log R \quad \text{Eq 10-6}$$

Where R is in feet from the center of the source. Measure R as a "line of sight" distance.

SECTION 20

Dehydration

Natural gas and associated condensate are often produced from the reservoir saturated (in equilibrium) with water. In addition, the gas and condensate often contain CO₂ and H₂S which might require removal. This is frequently accomplished with aqueous solutions such as amines, potassium carbonate, etc. which saturate the gas or condensate with water. Liquid hydrocarbons may also contain water downstream of product treaters or upon removal from underground storage.

Dehydration is the process used to remove water from natural gas and natural gas liquids (NGLs), and is required to:

- prevent formation of hydrates and condensation of free water in processing and transportation facilities,
- meet a water content specification, and
- prevent corrosion

FIG. 20-1
Nomenclature

| | |
|--|--|
| <p>A = area, ft²</p> <p>B = constant in Equation 20-11</p> <p>C = constant in Equation 20-11</p> <p>C_p = heat capacity, Btu/(lb · °F)</p> <p>C_g = gravity correction factor for water content</p> <p>C_s = salinity correction factor for water content</p> <p>C_{ss} = saturation correction factor for sieve</p> <p>C_T = temperature correction factor</p> <p>D = diameter, ft</p> <p>d = depression of the water dewpoint or the gas hydrate freezing point, °F</p> <p>EOS = Equation of State</p> <p>F_s = sizing parameter for packed towers, $\sqrt{\text{lb}/(\text{ft} \cdot \text{sec})}$</p> <p>G = mass velocity, lb/(ft² · hr)</p> <p>H = enthalpy, BTU/lb</p> <p>ΔH = latent heat of vaporization, Btu/lb</p> <p>K_{vs} = vapor/solid equilibrium K-value</p> <p>L = length of packed bed, ft</p> <p>L_g = glycol flow rate, U.S. gal./hr</p> <p>L_{MTZ} = length of packed bed mass transfer zone, ft</p> <p>L_s = length of packed bed saturation zone, ft</p> <p>ṁ = mass flow rate, lb/hr</p> <p>MTZ = mass transfer zone</p> <p>MW = molecular weight</p> <p>MW_i = molecular weight of inhibitor</p> <p>N = number of theoretical stages</p> <p>P = pressure, psia</p> <p>ΔP = pressure drop, psi</p> <p>q = actual gas flow rate, ft³/min</p> <p>Q = heat duty, Btu/hr</p> <p>Q_c = reflux condensing heat duty, Btu/gal.</p> <p>Q_{hl} = regeneration heat loss duty, Btu</p> <p>Q_r = total regeneration heat duty, Btu/gal.</p> <p>Q_s = sensible heat, Btu/gal.</p> <p>Q_{si} = duty required to heat mole sieve to regeneration temperature, Btu</p> <p>Q_{st} = duty required to heat vessel and piping to regeneration temperature, Btu</p> <p>Q_{tr} = total regeneration heat duty, Btu</p> | <p>Q_v = vaporization of water heat duty, Btu/gal.</p> <p>Q_w = desorption of water heat duty, Btu</p> <p>S_s = amount molecular sieve req'd in saturation zone, lb</p> <p>t = thickness of the vessel wall, in.</p> <p>T = temperature, °F</p> <p>T_{rg} = regeneration temperature, °F</p> <p>v = vapor velocity, ft/sec</p> <p>V = superficial vapor velocity, ft/min</p> <p>ḡ = water rate, lb/hr</p> <p>W = water content of gas, lb/MMscf</p> <p>W_{bb1} = water content of gas, bbl/MMSCF</p> <p>W_r = water removed per cycle, lb</p> <p>x = mole fraction in the liquid phase</p> <p>X = mass fraction in the liquid phase</p> <p>y = mole fraction in the gas phase</p> <p>z = compressibility factor</p> <p>γ = specific gravity</p> <p>μ = viscosity, cp</p> <p>ρ = density, lb/ft³</p> <p>Subscripts</p> <p>i = inlet</p> <p>o = outlet</p> <p>l = liquid</p> <p>v = vapor</p> <p>t = total</p> <p>CO₂ = carbon dioxide</p> <p>H₂S = hydrogen sulfide</p> <p>HC = hydrocarbon</p> <p>s = solid phase</p> <p>L = lean inhibitor</p> <p>R = rich inhibitor</p> <p>I = inhibitor</p> <p>H₂O = water</p> <p>H = hydrate</p> <p>rg = regeneration</p> <p>f = feed</p> <p>p = permeate</p> <p>i = any component in a mixture</p> |
|--|--|

Example 20-11—30 MMscf/d of a 0.65 sp gr natural gas enters a TEG contactor at 600 psia and 100°F. Outlet water content specification is 7 lb H₂O/MMscf and the TEG circulation rate is 3 gal TEG/lb H₂O. Estimate the contactor diameter and number of bubble cap trays or height of structured packing required to meet this requirement. Assume $z = 0.92$.

Solutions Steps:

1. Estimate required TEG concentration from Fig. 20-68
 H₂O Dewpoint = 24°F, which from Fig. 20-4 is equivalent to a water content of 7 lb H₂O/MMscf @ 600 psia
 Assume a 10°F approach to equilibrium
 @ T = 100°F, lean TEG concentration ≈ 98.8 wt%
2. Estimate number of theoretical stages.
 Calculate water removal efficiency

$$\frac{W_{in} - W_{out}}{W_{in}} = \frac{90 - 7}{90} = 0.922$$

From Fig. 20-70 ($N = 1.5$) at 3 gallon TEG/lb H₂O and 99.0 wt% TEG

$$(W_{in} - W_{out})/W_{in} = 0.885$$

From Fig. 20-71 ($N = 2.0$) at 3 gallon TEG/lb H₂O and 99.0 wt% TEG

$$(W_{in} - W_{out})/W_{in} = 0.925$$

use $N = 2.0$

2 theoretical stages \cong 8 bubble cap trays @ 24 inch tray spacing

FIG. 20-61

Hydrate Inhibition with Methanol: Hammerschmidt vs. Experimental Data²⁸

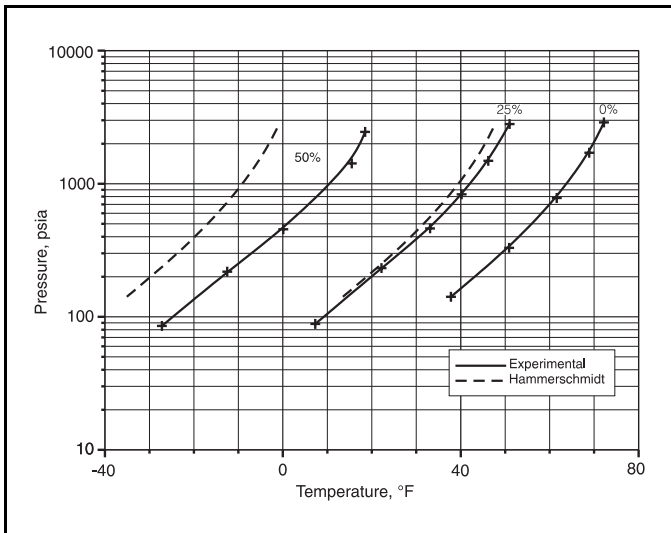


FIG. 20-62

Hydrate Inhibition with Methanol: Nielsen & Bucklin vs. Experimental Data²⁸

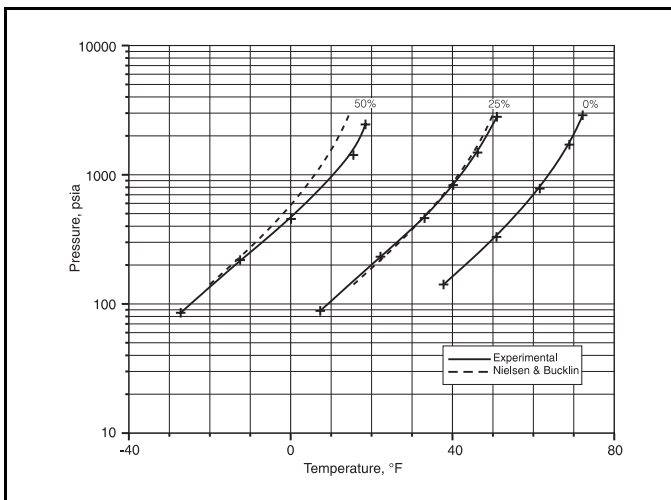


FIG. 20-63

Hydrate Inhibition with Methanol: Nielsen & Bucklin²⁶ vs. Experimental Data²⁹

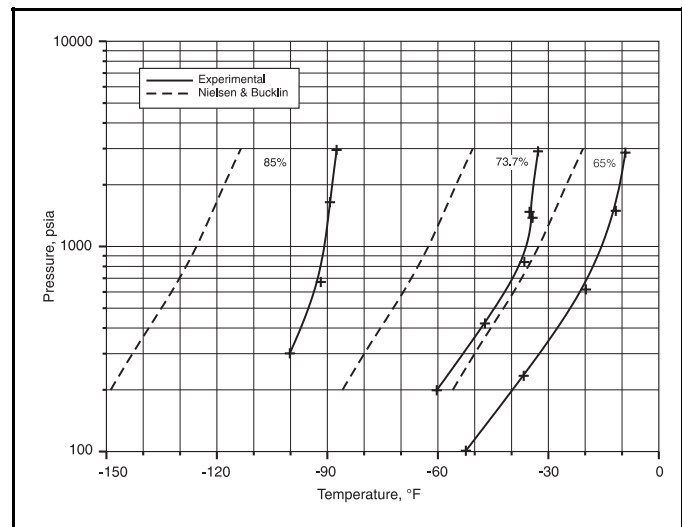
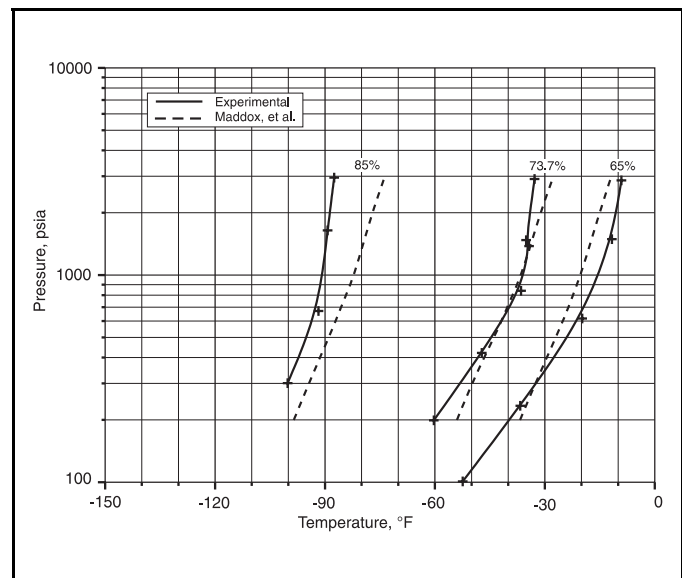


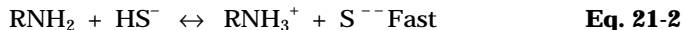
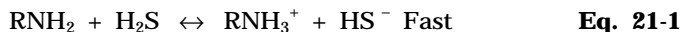
FIG. 20-64

Hydrate Inhibition with Methanol: Maddox et al.²⁷ vs. Experimental Data²⁹



Chemistry — The overall equilibrium reactions applicable for H₂S and CO₂ and primary and secondary amines are shown below with a primary amine⁹. A qualitative estimation of the velocity of the reaction is given.

For hydrogen sulfide removal



The overall reactions between H₂S and amines are simple since H₂S reacts directly and rapidly with all amines to form the bisulfide by Eq. 21-1 and the sulfide by Eq. 21-2.

For carbon dioxide removal

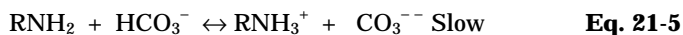
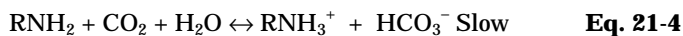


FIG. 21-3
Approximate Guidelines for Amine Processes¹

| | MEA | DEA ⁽⁹⁾ | DGA [®] | Sulfinol | MDEA ⁽⁹⁾ |
|---|--------------|--------------------|------------------|------------------|---------------------|
| Acid gas pickup, scf/gal @ 100°F, normal range ⁽²⁾ | 3.1–4.3 | 6.7–7.5 | 4.7–7.3 | 4–17 | 3–7.5 |
| Acid gas pickup, mols/mol amine, normal range ⁽³⁾ | 0.33–0.40 | 0.20–0.80 | 0.25–0.38 | NA | 0.20–0.80 |
| Lean solution residual acid gas, mol/mol amine, normal range ⁽⁴⁾ | 0.12 ± | 0.01 ± | 0.06 ± | NA | 0.005–0.01 |
| Rich solution acid gas loading, mol/mol amine, normal range ⁽³⁾ | 0.45–0.52 | 0.21–0.81 | 0.35–0.44 | NA | 0.20–0.81 |
| Solution concentration, wt%, normal range | 15–25 | 30–40 | 50–60 | 3 comps., varies | 40–50 |
| Approximate reboiler heat duty, Btu/gal lean solution ⁽⁵⁾ | 1,000–1,200 | 840–1,000 | 1,100–1,300 | 350–750 | 800–900 |
| Steam heated reboiler tube bundle, approx. average heat flux, Q/A = Btu/hr-ft ² ⁽⁶⁾ | 9,000–10,000 | 6,300–7,400 | 9,000–10,000 | 9,000–10,000 | 6,300–7,400 |
| Direct fired reboiler fire tube, average heat flux, Q/A = Btu/hr-ft ² ⁽⁶⁾ | 8,000–10,000 | 6,300–7,400 | 8,000–10,000 | 8,000–10,000 | 6,300–7,400 |
| Reclaimer, steam bundle or fire tube, average heat flux, Q/A = Btu/hr-ft ² ⁽⁶⁾ | 6–9 | NA ⁽⁷⁾ | 6–8 | NA | NA ⁽⁷⁾ |
| Reboiler temperature, normal operating range, °F ⁽⁸⁾ | 225–260 | 230–260 | 250–270 | 230–280 | 230–270 |
| Heats of reaction, ⁽¹⁰⁾ approximate: Btu/lb H ₂ S | 610 | 555 | 674 | NA | 530 |
| Btu/lb CO ₂ | 825 | 730 | 850 | NA | 610 |
| NA — not applicable or not available | | | | | |

NOTES:

1. These data alone should not be used for specific design purposes. Many design factors must be considered for actual plant design.
2. Dependent upon acid gas partial pressures and solution concentrations.
3. Dependent upon acid gas partial pressures and corrosiveness of solution. Might be only 60% or less of value shown for corrosive systems.
4. Varies with stripper overhead reflux ratio. Low residual acid gas contents require more stripper trays and/or higher reflux ratios yielding larger reboiler duties.
5. Varies with stripper overhead reflux ratios, rich solution feed temperature to stripper and reboiler temperature.
6. Maximum point heat flux can reach 20,000–25,000 Btu/hr-ft² at highest flame temperature at the inlet of a direct fired fire tube. The most satisfactory design of firetube heating elements employs a zone by zone calculation based on thermal efficiency desired and limiting the maximum tube wall temperature as required by the solution to prevent thermal degradation. The average heat flux, Q/A, is a result of these calculations.
7. Reclaimers are not used in DEA and MDEA systems.
8. Reboiler temperatures are dependent on solution conc. flare/vent line back pressure and/or residual CO₂ content required. It is good practice to operate the reboiler at as low a temperature as possible.
9. According to Total.
10. B.L. Crynes and R.N. Maddox, Oil Gas J., p. 65-67, Dec. 15 (1969). The heats of reaction vary with acid gas loading and solution concentration. The values shown are average¹⁰.